

A NEW
E S S A Y
ON ^{781. e. 5.}₂
MUSCULAR MOTION.

FOUNDED ON
Experiments, Observations,
AND THE
NEWTONIAN PHILOSOPHY.

By *BROWNE LANGRISH*, Surgeon,
at *Petersfield* in *Hants.*



L O N D O N :

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NEW

PHYSICAL

MUSCULAR MOTION.

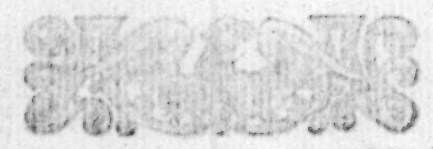
Found in

Experiments



NEWTON

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L O N D O N :

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To the HONOURABLE

Sir *HANS SLOANE*, Bart.

PRESIDENT of the

College of Physicians;

And PRESIDENT of the

ROYAL SOCIETY;

THIS

E S S A Y

Is, with all Respect and Humility, DEDICATED, by

His most Obliged, and

Most Obedient

Humble Servant,

Browne Langrish.

To the Honorable

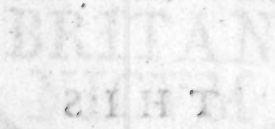
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*I*N the ensuing Discourse I have endeavoured to discuss several abstruse and knotty Points in Philosophy; I have accounted for Muscular Motion after a Manner intirely agreeable (at least I think so) to the Principles of that most illustrious Philosopher Sir ISAAC NEWTON; and in doing of this, I have occasionally taken Notice of the Laws of Attraction and Repulsion, from whence I have made it appear to be very probable, if not certain, that every individual Corpuscle of Matter is
 endued

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endued with its determinate Poles, and does attract or repel every other similar Corpuscle, which comes within the Sphere of its Activity, by the same Laws, and after the same Manner that two Loadstones influence each other.

FROM these Principles I have also deduced the Cause and Manner of an Effervescence or Ebullition, which arises from the Mixture of an Acid with an Alkali, and have proved that it does not depend so much upon the Power of Attraction as hath been hitherto imagined, but that a repellent Force between their constituent Particles, is the chief Reason of it; and from the same Qualities, viz. from every Corpuscle being endued with its determinate Poles, I have shewn the Reason why different Kinds of Salts always coalesce into Crystals of different Shapes, Forms, and Figures from each other, and why they always preserve their peculiar Shapes, let them be dissolved, filtered, and crystallized ever so often.

I HAVE

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I HAVE likewise demonstrated, from the Structure of the Nerves, that neither Muscular Motion nor Sensation could be performed distinctly, if they arose from any Vibrations in the Nerves themselves. And lastly, I have made it appear to be very probable, that the Use of the Ganglions on the Nerves, is to intercept any vibratory Motion which may happen in them; so that, by preventing any Communication of Motion from one Nerve to another, they are greatly instrumental in conveying the Ideas of Pleasure or Pain, or the various Impressions made on the Nerves, distinctly, from the several Parts of the Body, to the Sensorium in the Brain.

NOW since I have undertaken so arduous a Task, I hope every Gentleman, endued with a Taste for Enquiries of this Nature, will read what I have here done with Candour, and be ready to make favourable Allowances, especially when he considers that Muscular Motion is a Subject which has hitherto baffled the most curious Researches,

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Researches, and by some of the greatest and most learned Philosophers has been set aside as inexplicable. But if I have advanced any Thing inconsistent with the Animal Oeconomy, or with the known Laws of Matter and Motion, I shall always be ready to relinquish my most darling Notions whenever they are made appear not grounded on the Laws of Nature.



ERRATA.

PAge 18. line 5. dele *that*. p. 27. l. 9. for *the South Pole of one Magnet is offered to the same Pole of another*, read *both the South Poles or both the North Poles are put together*. p. 32. l. 13. dele *attracting*. *ibid.* l. 18. for *that* r. *than*. p. 33. l. 4. for *if once* r. *when*. p. 34. l. 4. dele *they*. *ibid.* l. 6. for *from whence* r. *that*. p. 43. l. 2. for *to* r. *from*. p. 44. l. 6. dele *been*. *ibid.* l. 7. for *through* r. *through*. p. 65. l. 8. dele *that*. p. 67. l. 19. for *so that* r. *but*. p. 68. l. 14. dele *only*. p. 69. l. 8. for *of* r. *in*. p. 73. l. 14. for *Glisson* r. *Glisson's*. p. 99. l. 8. for *the Causes of these Principles are kept as Secrets*, read *the Cause of these Principles is kept as a Secret*. p. 100. Margin. Note, for *Medicine* r. *Religion*.



not intirely agreeable to that Simplicity Regularity, and Harmony which we constantly observe between all the Parts of an animal Machine, is not to be conceived as Truth, but as a Fiction, and is only a Fiction.

A NEW
ESSAY
ON
MUSCULAR MOTION.

MUSCULAR MOTION is so intricate a Subject, that, amidst all the Varieties of Nature, there is not one Thing wherein the Cause is more concealed, tho' the Effect is so visible. It is a Subject which has already exercised the Wits of a great many learned and ingenious Men, and tho' so many Hypotheses have been invented concerning it, that it would be tedious as well as uninstruative to enumerate them; yet I don't know of one which will stand

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the Test of a strict Examination, without appearing to be inconsistent with some Part or other of the Animal Oeconomy; and certainly whatever is not intirely agreeable to that Simplicity, Regularity, and Harmony which we constantly observe between all the Parts of an animal Machine, is not to be received as Truth, let it be ever so wittily and ingeniously contrived.

SINCE therefore so many great and perplexing Difficulties attend the Explication of the Cause of *Muscular Motion*, I am afraid of being accused of Arrogancy in presuming to offer some Thoughts that have occurred to me on this Subject; but as I am fully persuaded that *Muscular Motion* is mechanically performed, and consequently, that it is governed by the known Laws of Matter and Motion, I flatter myself that some proper Experiments, with an exact Observance to the Laws of the Animal Oeconomy, and a diligent Application of some noble Discoveries that have been lately made in Natural Philosophy, will afford us a great deal of Light towards investigating the true Cause of *Muscular Motion*, however dark
and

and obscure it may seem at present; and if I am not so happy as to explore all its Secrets, yet I hope, at least, to excite some better Genius to perform the Task.

IT must be confessed indeed, that the principal Agent in *Muscular Motion* is too subtile for us ever to bring its Manner of Action to a mathematical Demonstration; but however if we can be so happy as to produce a Theory, every Way consonant with the Structure and Make of the Muscular Fibres, and with the known Laws of Matter and Motion, and it does not at the same Time, in the least clash with, or obstruct any of the animal Functions, there can be no Reason for rejecting it, tho' it cannot be mechanically explain'd.

THE noble BOYLE || says, " If a Matter of Fact, or other Proposition be proved by Arguments competent in their Kind, we ought not

|| Rules for judging of Things above Reason.

“ to deny it meerly because we cannot explain,
 “ or perhaps so much as conceive the Modus
 “ of it.

BUT lest I should incur the Displeasure of my Reader, by finding Fault with other Men's Works, or by making a long apologetic Introduction to my own, I will proceed directly to my Subject, and endeavour, according to my poor Abilities, to investigate the true and real Cause of *Muscular Motion*; wherein, if I err, or if my Hypothesis should be proved to be quite false, I shall have the Satisfaction of finding myself in very good Company; and the Choices on the wrong Side will be fewer by one, for those who shall hereafter undertake to explain the Cause of *Muscular Motion* by mechanic Principles.

THE Method I shall take, in order to unlock this Cabinet of Wonders, will be,

I. *By the Help of some Experiments which I have made on the Nerves and Blood-Vessels.*

II. *By looking into and nicely examining the Form and Figure of a muscular Fibre.*

III. *By accounting for its Elasticity.*

IV. *By shewing the true Cause of its Tension.*

V. *By proving it to be more than probable that there is some subtile, volatile, spirituous Matter, or animal Spirits secreted from the Blood by the Glands of the Brain, and continually flying into the Nerves.*

VI. and Lastly, *I shall deduce the Cause and Manner of Contraction and Dilatation in the muscular Fibres from the foregoing Considerations.*

I. IT has been always acknowledged and taken for granted, that if a Nerve be tied up, or cut asunder, the Muscles which that Nerve leads to immediately lose their Use, tho' all other Things continue the same; and from many Experiments which I have made on the Nerves, I have always found

found this to be exactly true: But that tying up the crural Artery, or any other Artery, out of the Trunk of the Body, will likewise destroy *Muscular Motion*, I have proved to be false, by the following Experiments.

EXPERIMENT I.

I TIED up the right Inguinal Artery of a Dog, and cut it off just below the Ligature, that I might be sure there was no Blood continued to circulate thro' it; the Dog being immediately set down, walked along as well as usual, tho' as the Wound grew more sore and stiff, he limped a little sometimes; but when the Wound was healed up, I could never afterwards perceive the least Difference in the Motion of his hind Legs.

EXPERIMENT II.

I TIED up the right Carotid Artery as near the Heart as I could possibly do it, and cut it off above the Ligature; but the Dog did not lose the
Use

Use of any one Muscle by it : considering then that there were frequent Inosculations between the ultimate Branches of the Carotid Arteries, I served the left Carotid Artery of the same Dog in the same Manner, and yet there was no Loss of Motion ; he could lap up Milk, chew Meat, swallow, wink, and use all the Muscles of the Head, Mouth, and Face as he used to do.

EXPERIMENT III.

I TIED up and cut asunder both the Inguinal and both the Carotid Arteries of a large Spaniel Dog which I now keep, and yet this Dog has not lost the Use of one Muscle, neither is he disordered in any one Way by it, that I know of, tho' it is now above six Months ago that I did it.

THESE Experiments are sufficient to shew, how much People have been deceiv'd, and how erroneous the common Opinion is, viz. *That if the Crural Artery was to be tied up, or cut asunder, the Muscles of the Leg would lose their Use as certainly, as if the Crural Nerve was destroy'd.*

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THIS Assertion was spread abroad, as I am apt to believe, without making any, or sufficient Trials of it; for I have repeated these Experiments a great many Times, and I am sure with the utmost Accuracy, and always with the same Success. 'Tis true, we are not to infer from hence, that the Blood has nothing to do with *Muscular Motion*, because there are most certainly some small Branches detached off from the Inguinal and Carotid Arteries nearer to the Heart, than we can possibly lay any Ligatures on them without destroying the Life of the Dog; so that we are not to suppose the *Muscles* are quite destitute of Blood, because their main or principal Artery is tied up, or cut asunder, it being well known that when all the Blood is intercepted, *Muscular Motion* ceases in a few Minutes.

THIS appears to be true by tying up the *Aorta descendens*, which I have often done, just before its Division into the *Iliacæ*, and I always have observed, that if the Dog was set down immediately after the *Aorta* was tied up, (without staying to replace the Intestines, or to sew up the Wound) he
could

could make Use of his lower Parts, and walk a little Way, before the Palsy seiz'd him, but after that no manner of Motion could be perceived in his hind-Legs, tho' he would sometimes survive the Operation seven, or eight Hours.

SEEING therefore that *Muscular Motion* is so soon destroyed, when all the Blood is intercepted, I beg Leave to propose the following Queries concerning the Reason of it.

Q U E R Y I.

D O E S not the violent Distension of the *Aorta*, and all the neighbouring Blood-Vessels above the Ligature press upon the Nerves, which go to the lower Parts, and by that Means interrupt the Passage of the Animal Spirits thro' them; since 'tis well known, that in a *Nephritis* the Thigh often loses great Part of its Motion and Sensibility by the Stones pressing upon the Nerves?

C Q U E R Y

QUERY II.

DOES not the Pulsation or Vibration of the Arteries greatly assist the Motion of the Animal Spirits thro' the Nerves? For since the Nerves are generally placed along the Sides of the Arteries, it is humbly presumed that the Design of it was to encourage the Motion of the Animal Spirits thro' the Nerves. Now if so, it follows, that tho' some of the Nerves, which go to the lower Parts, may arise below the Place where the *Aorta* is tied up, and others escape the Pressure of the distracted Blood-Vessels above the Ligature, yet the animal Spirits may want the proper and usual *Impetus* to propel them thro' the Nerves, and consequently *Muscular Motion* may be destroyed merely for Want of the vibratory Motion of the Arteries.

QUERY III.

DO not the muscular Fibres collapse, and grow so flaccid, when all the Blood is intercepted, that the Influx of the animal Spirits may be interrupted,

rupted, tho' no other Impediment should happen in the Nerves?

Q U E R Y IV.

Is not the chief Use of the Blood, towards *Muscular Motion*, to keep the Fibres warm, supple, distended, and every Way ready for the Influx of the animal Spirits into them; and by its expansive and progressive Motion, to assist the Motion of the animal Spirits through the Nerves?

We are assured by Mr. COWPER, that by injecting warm Water only into the Artery of Muscles concerned in voluntary Motion, after the Passage of the Blood had been intercepted, he caused them to renew their Contraction. Now warm Water cannot possibly have any other Effect on the muscular Fibres, than to distend, supple, and relax them, and, by its Warmth and progressive Motion thro' the Arteries, it may communicate Motion to the animal Spirits; but it is absolutely impossible for it to have any Share

in shrinking up or contracting the Fibres, after such a Manner as *Muscular Motion* is performed. That the Blood is useful towards *Muscular Motion*, either by encouraging the Motion of the animal Spirits through the Nerves, or by keeping the Muscles warm, supple, distended, and moist, in such a Manner that the animal Spirits have a free and easy Influx into them, cannot be denied; but that the Blood is by any Means capable of purring up and contracting the Fibres, does not appear from any Arguments which have been made Use of in its Favour. On the contrary, it has been proved, as we shall shew hereafter, that a Muscle, during its State of Contraction, is lessened in all its three Dimensions, and consequently the Blood, instead of swelling and distending the Fibres, is squeezed out of them at such a Time; so that, Action and Re-action being always equal, it appears from hence, that the Blood acts as an Antagonist, against the contractile Power of the Fibres, by extending and distending them, rather than having any Share in their Contraction.

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WE are told by the learned AUTHOR of the *Introduction to COWPER on the Muscles*, That the Blood appears some Way necessary towards *Muscular Motion*, since it has been found that, by intercepting the Passage of the Blood to any Muscle, the Muscle loses its moving Power. But from some Experiments on the Heart of an Eel and Salmon, (*viz.* that being warmed, they would beat long after the Death of the Animal, nay, even when separated from the Body) it may be questioned whether this Effect arises from any other Cause, than that by depriving the Muscle of its Blood, the Fibres and Nerves must soon grow cold and stiff: for we see in these Experiments, that the Fibres of the Heart, when warm, contracted themselves, tho' the Blood was not circulating thro' them.

THE Heart of a Frog is also very remarkable for continuing its Pulsation a long Time after it is taken out of the Body; and even after it has ceased beating, it will repeat it again by being warmed, or pricked with a Needle: But the most remarkable

remarkable of all is a Viper, which will continue to twist and twine about for many Hours after the Head, Heart, Entrails, and Skin are taken from it.

IN short, these Phenomena give great Room to suspect that *Muscular Motion* is continued in some Creatures as long as the Fibres are warm, moist, and supple; and that it arises only from some subtil Matter, or the animal Spirits, which momentarily increase the Force of the corpuscular Attraction in the Fibres themselves, so that their component Particles run closer together, and the Fibres are shortned as long as this additional attractive Power remains in them: But of this more hereafter. Thus much being premised, I go on to my

II^d HEAD, viz. *To examine into the Form and Figure of a Muscular Fibre.* And this is best done by gently boiling a Muscle till its Fibres will easily separate from each other, and then, if it be wash'd and cleansed from the Blood, &c. the Texture

Texture and Shape of the Fibrils become more evident and perspicuous.

WHEN a Muscle is prepared after this Manner, and a longitudinal Fibre divided as far as we possibly can do it, it always appears to me to be of a cylindrical Shape; and I am of Opinion, that if we could separate the Fibres much farther, or as far as they are capable of being divided, they would still be of the same Shape, *viz.* little hollow Cylinders; for tho' every minute Fibril is allowed to be the Continuation of a Blood-Vessel (a capillary Branch of an Artery being lost in it, and a capillary Branch of a Vein arising from it) yet it cannot properly be called either an Artery or a Vein, neither does it follow either of their Shapes.

As to the transverse or spiral Fibres, which are found in dividing a Muscle, they seem to me to be of the same Make with the others, and to be chiefly useful in holding the longitudinal Fibres in their proper Positions; but by the most accurate Observations, with the best of Glasses, I could

could never perceive that either the longitudinal or transverse Fibres were divided into Cells, Vesicles, or Bladders.

III. *The Elasticity of a Muscular Fibre* is a Power or Property of restoring itself to its former Shape, after it has been stretched out longer than usual by some impressed Force.

Now, in order to understand the Nature of this rightly, it will be proper to consider that there is in all Matter a peculiar Power of Attraction and Repulsion; which Properties manifestly discover themselves in many Things, and according to their particular Dispositions they are called by the Names of Magnetism, Electricity, or Gravity.

MAGNETICAL Attraction, strictly speaking, belongs to no other Bodies but the Loadstone, and Iron or Steel; at least it has not been discovered in any thing else. Electrical Bodies attract all light Things indifferently. And Gravity equally affects all Bodies, without regard either

to their Bulk, Figure, or Matter. But notwithstanding these seeming Differences in the Tendency of some Bodies towards others, we have many Reasons to believe that the real Cause of Attraction and Repulsion is the same in all Bodies, and that all these different Phenomena, as well as the various Degrees of Cohesion, Hardness, Elasticity, &c. arise only from so many different Degrees of Attraction and Repulsion between the component Particles, and not from any material essential Difference in the Cause. I never could find that there was any Difference between the Force of Attraction and that of Repulsion in the same Pole of a Loadstone, and if the same Pole both attracts and repels with the same Degree of Power, these Qualities seem very likely to proceed from the same original Cause.

AGAIN, if the original Cause of Attraction and Repulsion be the same in all Bodies; that is, if every Particle of Matter, which is endued with an attractive Force, is also endued with a repellent, in the same *Ratio*, 'tis very probable that these Qualities were equally impressed on all the original

ginal primitive Atoms of Matter at the Creation ; and that all the different Degrees of Attraction and Repulsion, which we now find in several Sorts of Bodies, proceed only from the various Shapes, Associations, and Combinations of their constituent Particles ; so that it is entirely owing to such and such particular Structures and Dispositions of the component Particles, that some Bodies are naturally receptive and retentive of Magnetism, others of Electricity, and others of neither of them, at least not within the Reach of our Senses.

SINCE therefore we have great Reason to believe that every Parcel of Matter is endued both with an attractive and repelling Force, in some Degree or other, and since these Vertues are more eminently conspicuous in a Loadstone than in any other Sort of Matter whatsoever ; I think we ought to fix that as the Standard, and deduce our Theory of Attraction and Repulsion from thence.

Tis

'T is well known that a Loadstone hath its determinate Poles, and that it does attract or repel every other Loadstone, placed within the Sphere of its Activity, according as their Poles are applied to each other; that is, if the South Pole of one Magnet be placed within a proper Distance of the North Pole of another, they will fly together, and embrace each other with the utmost Affection: but if the South Pole of one Magnet is offered to the same Pole of another, they will then avoid and fly from each other, with as much Velocity as they came together before. The very same Thing will happen between two magnetic Needles, or any Pieces of Iron or Steel properly touched with a Loadstone; nay, a magnetical Vertue may be communicated to Steel, by rubbing it between an Anvil and an Iron Bar, without ever touching a Magnet, and this as strong and permanent as possible, as Mr. ARNOLD MARCEL † (Ne-

† Phil. Transact. N^o 423.

phew to the late Mr. ANTHONY VAN LEEUVENHOEK) has lately discovered.

IF a Loadstone be broke into ten thousand Pieces, every Fragment will have its determinate Poles, and will preserve its attractive and repellent Qualities in Proportion to its Bulk; from whence it appears, that the constituent Particles of a Magnet are all of them placed Rank and File, in a very regular Manner, and that they are all endued with their proper Poles; because, break the Stone where you will, the Consequence is the same: And from hence, likewise, 'tis evident, that the Strength of the Attraction and Repulsion, whilst the Magnet was whole, proceeded from the Share which every individual Corpuscle contributed towards it.

THE whole Earth is allow'd to be a Magnet; and there is no doubt but its Poles have the same Influence on all the heavenly Bodies, which are within the Sphere of its Attraction and Repulsion, as we observe between those of two Loadstones; and it must be confess'd, that the Sum of the
attractive

attractive and repulsive Force of the whole Earth, or of any Part of it, arises from the Share which every constituent Particle contributes towards it: For tho' some Parts of Matter are endued with a stronger and more visible attractive Force than others are; yet it cannot be denied but every the minutest Particle has this Property, and consequently it must have its Influence in a *Ratio* to its attractive Force, and to the Proportion it bears to the Whole.

THIS is exactly agreeable to what the inimitable Sir ISAAC NEWTON has shewn us in his *Principia*, viz. "That the Quantity of the Force of Attraction in all similar Bodies, at equal Distances, is exactly proportionable to the Quantity of Matter in the attracting Body, as being in Reality nothing but the Result or Sum of the united Forces of all those single Particles of which it is composed."

HENCE it appears, that if the Attraction and Repulsion, or the different Poles of our Earth, or any Part of it, arise only from the
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Union or Conjunction of the attractive and repellent Force of all its component Particles, that then each single Corpuscle in every Parcel of Matter, must have its determinate Poles, (it being impossible for it to communicate what it has not) and does attract or repel every other similar Corpuscle, which comes within the Sphere of its Activity, according as their Poles happen to be offered to each other; and though these Properties are not active enough in many Things to produce visible Effects, yet we have all the Reason in the World to believe that every Parcel of Matter is endued with the same Principles, though they may be in several Degrees, or they may be intended or remitted according to the different Shapes, Textures, and Modifications of the component Particles.

It is to these Properties of Attraction and Repulsion that we attribute the intestine or fermentative Motion which arises in the Dissolution of some Bodies; for though it may be easily conceived that Salt or Sugar may be dissolved by the Strength of Attraction only, yet I can't
appre-

apprehend how an Ebullition can proceed from the Mixture of different Bodies, without a repellent Force between some of their Particles. As, for Instance, I presume, from what has been said, that all the constituent Particles in Salt of Wormwood have their determinate Poles, and are all placed, by the common Laws of Attraction, in a regular Manner, according to their Poles; and consequently, as long as they remain in such Positions, all is quiet; but as soon as some Juice of Lemons, or any other Acid, is poured upon it, the acid Particles attract some of the saline Particles much more violently than they did each other before, and repel others with as great a Force, according as their Poles happen to meet: Hence arises a great Commotion between the acid and alkaline Particles; and from this leaping and bounding about of them, proceeds an Ebullition; and this Ebullition or Effervescence continues till all the Particles, both acid and alkaline, have met with each other at their proper Poles of Attraction; which is no sooner done, but the Ebullition ceases, the Mixture subsides, and the acid and alkaline Particles
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are united in a very friendly manner ; that is, they attract and are attracted by each other, without any repellent Force acting among them.

I VERY well know that some great and learned Men have thought, where the attracting Corpuscles of any Fluid are elastic, they must necessarily produce an intestine Motion ; and this greater or lesser, according to the Degrees of their Elasticity and attractive Force. But, with all due Submission, I am of Opinion, that Repulsion has much more to do in Ebullitions or violent Fermentations, than Attraction ; for, supposing any Number of elastic attracting Particles to be within the Sphere of each other's Attraction, and that they fly together with any given Force, it will follow, that the Strength of their Attraction will be so much greater at the Point of Contact, that it was at ever-so small a Distance before, that their Springiness or Elasticity will not be able to separate them again. For since the attractive Power is the first and only *Impetus* which puts the Particles in Motion, it must necessarily follow, that the Strength of the
Attraction

Attraction does increase in the same Proportion with the Velocity of the moving Particles, and consequently it will be sufficient to hold them together if once they come into Contact, let them be ever-so elastic.

THAT Bodies entirely elastic (if any such there are) may recede from one another, after they have met, with the same Celerity they had before they met, abating the Resistance of the *Medium*, cannot be denied, when the *Impetus* is communicated to them from a third Body, and the moving Bodies have no attractive Influence on each other, even in Contact: But by all the Observations I have been capable of making, I never could perceive that any Bodies which flew together from the Principle of Attraction only, ever separated again, unless they were attracted or repelled more forcibly by some other Body. Whereas, if we suppose the Particles of fermenting Liquors to be endued with their determinate Poles, 'tis evident that some of them must recede from, whilst others fly towards each other; and during such Commotions there must be violent

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Collisions: because all those Corpuscles which are repelled, and in their Flight strike against others, and their Poles, don't happen to agree, they will have so many fresh Impulses communicated to them, by their repellent, as well as by their elastic Force; from whence their Velocities will be prodigiously increased; and thus they will keep on dashing from one to the other, till they are broke into their *Minima*, or till all the component Particles are settled according to their different specific Gravities and Attractions.

'Tis well known, that in an Ebullition the Mass of Matter is rarified; that is, its Parts are so divided, as to occupy more Space than they did before, and to have their Interstices larger than before; which is not so likely to arise from the Principle of Attraction, as Repulsion. Add to this, That the Attraction between the most minute Particles of fermenting Liquors, exerts itself only at the least sensible Distance; whereas, by many Experiments, we have discovered, that a repellent Force acts at a greater Distance;

Distance; insomuch that when the same Particles which attracted each other before, are posited without their Sphere of Attraction, they will still repel, and endeavour to fly farther from each other. Hence it evidently appears, that in all Effervescencies a vast many more Particles must be influenced by a repellent, than by an attractive Force; and as Effects are ever proportionable to their adequate Causes, it consequently follows, that all violent Fermentations or Ebullitions are owing more to the Power of Repulsion than Attraction.

I AM persuaded also, that Salts always preserve their particular Shapes, Forms, and Figures, (though they are dissolved, filtered, and crystallized ever-so often) by every Particle having its determinate Poles: For, granting that the component Particles of different Kinds of Salt are of so many different Shapes and Sizes; yet if they had a Power of uniting with each other indifferently at their Tops, Bottoms, and Sides, one would think they could not always coalesce into Crystals of the same regular Figure. But if

the constituent Particles of any Kind of Salt are of such a peculiar Shape, and at the same time have their determinate Poles, then they cannot possibly attract or unite with each other, but when their Poles square with one another, and consequently they will always fly together, and be join'd at such Points only where their corresponding Poles are, which must of Course constantly produce the same regular Form and Figure in every Aggregate of such particular saline Particles. As for Instance, *Sal Armoniac* very elegantly imitates the Branches of a Tree, Salt of Hartshorn looks like a Quiver of Arrows, and Salt of Tin shoots into Lines like little Needles, which spread themselves every way from a Point, as from a Centre, so as to represent a Star.

Now can it be imagined, if the most simple Atoms or Parts of these Salts did attract each other indifferently on either Side, that they would immutably and perpetually coalesce into Crystals of the same regular Figure and Shape?

THE learned Dr. FREIND || lays it down as a *Lemma*, "That the attractive Force is greater "on one Side of the same Particle, than on another ;" but he does not suspect that it arises from the same Principle that influences a Loadstone, or that the other Side has its contrary Pole. However, Sir ISAAC NEWTON observes, † "when any saline Liquor is evaporated to a Cuticle, and let cool, the Salt concretes in regular Figures ; which argues, that the Particles of the Salt, before they concreted, floated in the Liquor, at equal Distances, in Rank and File, and by Consequence, that they acted upon one another by some Power which at equal Distances is equal, at unequal Distances is unequal ; for, by such a Power, they will range themselves uniformly, and, without it, they will float irregularly, and come together as irregularly. And since the Particles of Island Crystal act all the same way

|| Chymical Lectures.

† Opticks, Book III. Qu. 31.

upon

“ upon the Rays of Light, for causing the unusual
“ Refraction ; may it not be supposed, that in
“ the Formation of this Cryſtal, the Particles not
“ only ranged themſelves in Rank and File for
“ concreting in regular Figures, but alſo by
“ ſome kind of polar Virtue turn'd their homo-
“ geneal Sides the ſame way ?

AND again, we are taught by the ſame
Great Man, “ That Fire is the moſt ſimple of
“ all known Bodies, and conſequently the moſt
“ immutable : That each Ray of Fire or Light
“ has Sides differently affected, and which have
“ different Properties ; and that Iceland Cryſtal
“ is found to attract a Corpufcle of Fire, if one
“ of its Sides be turned toward the Cryſtal, and
“ repel it, if the other be. For one and the
“ ſame Ray is here refracted ſometimes after the
“ uſual, and ſometimes after the unusual manner,
“ according to the Poſition which its Sides have
“ to the Cryſtal ; and ſince the Cryſtal, by this
“ Diſpoſition or Vertue, does not act upon the
“ Rays, unleſs when one of their Sides of unusual
“ Refraction looks towards that Coaſt, this
“ argues

“ argues a Virtue or Disposition in those Sides
“ of the Rays, which answers to, and sympathizes
“ with that Virtue or Disposition of the Crystal,
“ as the Poles of two Magnets answer to one
“ another.”

THERE are many Experiments, too tedious to mention now, which not only confirm the Truth of these Things, but induce one to believe that all the *Phænomena* of Nature do arise from the constituent Particles of Bodies being either impelled towards each other, and cohering in particular and regular Figures, according to their Poles, or else by being repelled and receding from each other; and though the real Cause of Attraction and Repulsion is one of the Secrets of Nature, and, I believe, likely to continue so, yet, by frequent Observations, we are arrived to a tolerable Certainty in accounting for their different Laws, and are able to deduce many useful Problems from thence.

AND

A N D here I cannot but observe, That as each original primitive Particle or Atom of Matter must have its determinate Magnitude or Size, as also its peculiar Figure and Shape; so from a few different Sizes and Shapes, among the primitive Atoms, may arise all the wonderful Varieties of Matter, wherewith the World is adorn'd; according to their different Compositions, Associations, or Modifications. For if we consider from how few original primary Colours we are able to produce an infinite Number of others by variously mixing them, and that from twenty-four Letters we have formed Languages consisting of an infinite Number of Words; it appears to be possible for all the different Species in the animal, vegetable, and mineral Kingdom, to proceed from a few original Shapes and Sizes first impressed on the Atoms; especially since 'tis well known that Nature is always frugal in Principles, though fruitful and various in Effect and Compositions. But to return :

WE have not yet taken sufficient Notice of that Sort of repellent Force in Matter, which arises from the Particles being placed beyond the Sphere of each other's Attraction, as between Water and Oil, and generally between Water and all unctuous Bodies; between Mercury and Iron; and also between the Particles of any Dust. But the most remarkable Repulsion of this Kind is in the Air, where the component Particles endeavour to expand and recede from one another with a mighty Force, so as to be the sole Cause of its wonderful Elasticity, which is so great, that all the Compression in the World is not able to overpower it, or to condense its constituent Particles near enough together to come within the Sphere of each other's Attraction.

THE more the Air is compressed, and its Density increased, the more elastic it is; because the nearer its Particles are squeezed together, the more they repel and endeavour to fly from each other: And let the compressive Power be ever-so great, or continue ever-so long, the

Moment it is taken off, the constituent Particles of the Air will expand and recede from one another with a Velocity proportionate to the Compression; that is, the Force by which the Particles of Air fly from each other, increases in the same Ratio as the Distance in which the Centres of the Particles are diminish'd; or, in other Words, the repelling Force is inversely as this Distance.

BUT notwithstanding the Elasticity of the Air proceeds intirely from a repellent Force between its component Particles, 'tis not to be infer'd from thence, that the Elasticity of solid Bodies arises merely from the same Cause; because it is evident that their Particles are all in Contact with each other, before the elastic Body is bent or drawn out longer than usual by some impressed Force. As for Instance: Whilst a Spring is straight, we presume, every individual Particle of it is at Rest; that is, they are situated, in regard to each other, according to their Poles, and embrace one another by their common Principle of Attraction; but no sooner is the Spring bent, but some of

of its Particles, on the convex Side, must of Course be disjoined and removed to each other, though perhaps to the most minute and smallest Distances in the World, whilst others, on the concave Side, are crowded over one another. Hence it will follow, that if those Particles which are separated from each other, or touch one another in fewer Points than usual, are yet so near each other as to be within their Sphere of Attraction, and not at all altered in regard to their Poles, they will consequently attract each other very strongly, and fly together again as soon as the impressed Force is removed; whereas it is no unreasonable Conjecture to suppose those Particles, on the concave Side of the Spring, which are crowded together, and, as it were, rumpled over one another, may be so much altered from their former Positions, that their Poles do not now answer each other; and if not, they will repel one another till they have attained their former Situations, that is, till the Spring has recover'd its former Shape.

THERE are those indeed who have attributed the Cause of Elasticity to some subtile Matter which they suppose to be constantly flying through all Bodies, except elastic ones, when they are bent : As for Instance ; This subtile Matter is believed to have been a free and uninterrupted Passage throuh the Pores of a Spring whilst it remains straight ; but as soon as it is bent, the component Particles on the concave Side of the Spring are forced closer together, whilst those on the convex Side are removed farther asunder : So that though this subtile Matter enters more easily on the convex Side, yet it meets with much Opposition on the concave ; from whence there arises a constant Struggle between the subtile Matter, and those Particles of the Spring which are forced so near together as not to admit the subtile Matter to pass between them ; and as long as this *Nisus* remains, so long will the Spring be elastic.

BUT by the Assistance of the Doctrine of Attraction and Repulsion, taught us by our
Great

Great Master, Sir ISAAC NEWTON, we are able to account for the Cause of Elasticity after a more rational manner; and we are well assured that some soft malleable Bodies may be made elastic, and elastic Bodies may be made more so by such Things as will increase their Attraction, or unite their constituent Particles nearer together; and *vice versa*.

'Tis reported, * That touching a Steel Sword with a Loadstone, makes it more elastic; and if so, 'tis probable that this Effect arises from the component Particles of the Steel being drawn nearer together by the magnetic *Effluvia*, or else by their attractive Virtue being increased towards each other, though their Distances are not at all altered.

A PLATE of Metal, by repeated Blows of a Hammer, becomes elastic; and being heated, does again lose that Virtue.

* Switzer's Preface to his Hydrostatics.

AND 'tis well known, that if a Piece of Steel be heated to a great Degree, and suffered to grow cold gradually, it will lose the greatest Share of its Elasticity; whereas if it be suddenly immers'd in cold Water, whilst it is intensely hot, it loses but little or none of its elastic Force. Now this is most certainly owing to the component Particles of the Steel being displaced and separated from each other by the Force of the Fire, and suffered to remain so in the former Case, and to their being contracted or condensed in the latter. Every *Blacksmith* knows that Heat will swell and lengthen a Bar of Steel, and make it soft, supple, and unelastic; and there is no doubt but cold Water does contract it in Proportion, as being diametrically opposite in its Nature to Heat.

THUS much being premised, I shall now return to examine into the Cause of Elasticity in an animal Fibre, and am in Hopes that it will easily appear, from what has been said.

W H E N

WHEN a muscular Fibre is stretched out longer than usual, 'tis most certain, that some of its Particles slip by one another, and others are removed at exceeding small Distances from each other: and if the impressed Force is at any time greater than the Strength of the Attraction between the constituent Particles of the Fibre, a Solution of Continuity happens, or the Fibre breaks. Hence 'tis evident, that when a stretched-out Fibre retracts itself into its former Shape and Dimension, the Particles which were displaced, return again to their proper Positions, by their attractive Power. And this Consideration may possibly give us a great deal of Light, towards investigating the true and real Cause of *Muscular Motion*: For as all the Fibres in an animal Body are elastic, and as their Elasticity is a Power of Restitution, by which means they recover their former Shapes, after they have been stretched out longer than ordinary, it may reasonably be called a Contraction. And there is no doubt but if the same Cause which makes all the Fibres of a Muscle elastic, was to be suddenly increased, it would

would contract the Muscle still shorter, and be the Cause of *Muscular Motion* as long as such additional attractive Power continued in the Fibres.

ALL the Fibres of an animal Body are elastic not only during Life, but after Death; as is evident from Cat-gut, Parchment, Leather, &c. which are all made of the Skins and membranous Parts of animal Bodies. But then this is under some Limitations: For if the Fibres are in the least corrupted and putrified, their Elasticity is destroyed; or if they are made so dry that their constituent Particles cannot slip by each other, or yield to one another's Motion; they will break, if you offer to stretch or bend them with any Force. Hence it appears, that there is a peculiar Disposition or Arrangement of the component Particles required, in order to make the Fibres elastic; and that their Elasticity is easily destroyed by some Things, and increased by others.

ANY mucous slimy Matter in the Body (and from such Matter the Fibres are chiefly nourished) being

being temper'd between the Fingers 'till it will draw out into Strings, has this Property of Elasticity, or contracting itself, and growing thicker and shorter as soon as the Power which stretched it out is removed; and undoubtedly the Elasticity of an animal Fibre arises from the same Cause, *viz.* from the mutual Attraction of its constituent Particles.

By this elastic Power all the Fibres in an animal Body are kept in their proper Positions; so that whenever any of the Vessels are dilated, expanded, or distracted beyond their usual Dimensions, 'tis owing to this Property, that they are capable of restoring themselves to their natural Shapes: And how exceedingly useful this is towards preserving the Body, is evident to every one who is in the least acquainted with the animal Oeconomy. Without this Property in the Fibres, Life could not subsist but a few Hours, or perhaps Minutes; the Body would be like a Lump of Dough; Obstructions, Tumours, Distensions, and Swellings would arise every-where, and would soon put a Stop to the Circulation. But to proceed:

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THE Fourth Thing to be taken Notice of in a Muscle, is, That all its Fibres are, during Life, in a State of Tension; that is, every Fibre seems to be stretched out beyond its natural State of Rest or Quiescence; as is evident from an Incision made across any Muscle, which is no sooner done, but those Fibres which are cut asunder fly back like so many stretched Strings, and make the Wound gape.

NOW there are Two Things which seem to be principally concerned in this Action; The Impulse and Pressure of the circulating Fluids; And a constant *Nisus* or Endeavour towards Contraction in the Fibres. For as the Blood is always propelled with some Violence through the Vessels, it must necessarily extend and distract them in Proportion to its Quantity and Velocity; as is evident by cutting asunder an Artery or a Vein: But as the *Impetus* of the Fluids does only increase the Breadth and Length of the Fibres, we must have Recourse to some other Agent for their Contraction or flying back, when they happen

happen to be cut asunder. And if we accurately examine into the Nature of it, I am persuaded we shall find, that this Property in the muscular Fibres arises from the same Cause with their Elasticity, and perhaps with *Muscular Motion*. For, 1st, It appears, that when the Fibres are relaxed, that is, when they have lost their Elasticity, they will not retract, if cut asunder, though they are ever-so-much distended with Fluids ; as is evident in the worst Degree of an *Anasarca*. 2^{dly}, All the voluntary Muscles are preserved in *Æquilibrio* by an equal Degree of Tension in their Fibres : But whenever a voluntary Muscle loses its Use, its Antagonist immediately and involuntarily contracts itself, by Virtue of its Tension, and will remain in that State as long as the Relaxation or Weakness continues in the other ; which argues a great Analogy between the Cause of the Tension, and that of *Muscular Motion*. 3^{dly}, I have many times observed some Muscles and the fleshy Panicle of an Ox to twitch and contract a good while after he has been kill'd, and always found that as long as these *Muscular Motions* continued, so long would the Fibres retract, if

cut asunder, and not at all, or very little, afterwards.

HENCE it appears that the Fluids always act as an Antagonist against the retracting Power of the Fibres, by extending and dilating them; and as Action and Re-action are always equal, it may easily be conceived of what vast Use this is in the Animal Oeconomy. Besides, as the Tension of each voluntary Muscle is an exact Ballance to its opposite, it not only prevents any irregular Motions or Distortions in them, but it also prepares and makes them ready for voluntary Motion, upon the least Alteration of the Ballance: And let us add to this, If the Fibres were not tense, they could not be elastic; as it appears in Strings that have their Ends fixed, without being stretched or contracted; for if you remove them a little from their Position, they do not return to it: But what the Degree of Tension is, which gives Beginning to Elasticity, is not yet, that I know of, determined by Experiments.

FROM

FROM the different Degrees of Tension in the Fibres arise so many Constitutions; some being hard and brawny, and their Motions vigorous and strong, whilst others are flaggy, relaxed, and weakly. Now as these Constitutions are most times easily altered from one Side of the Ballance, or common Standard of Nature, to the other, and as it appears, at least to me, that the Cause of the Elasticity and Tension of the Fibres has a very near Affinity to that of *Muscular Motion*; I beg Leave to enquire a little after such Things as are commonly known to contract the Fibres, when applied to them; and from thence, perhaps, we may more easily investigate the true Cause of *Muscular Motion*.

I. IT is most certain, that all volatile spirituous Things increase the Tension of the Vessels, and invigorate their Motions; and this Effect is generally attributed to the Subtilty of their Particles, whereby they are capable of insinuating themselves into the Fibres, and exciting them more frequently into a contractile Motion.

II. ALL

II. ALL Astringents are well known to purse up, shorten, and contract the Fibres; and this they do, by sticking their acute Angles into the Vacuities or Interstices of the Fibres; by which Means they stimulate them into Motion, and increase the attractive Force of their component Particles towards each other.

III. A SUDDEN Application of any Thing extremely cold, will contract the Fibres, by condensing their component Particles nearer together, as well as the Fluids within them.

FROM hence it appears, without mentioning any more, That whatever is capable of drawing the constituent Particles of the Fibres nearer together, either by exciting them into Motion, or by increasing their attractive Virtue towards each other, will make them more elastic and tense: And if we should infer from what has been said, that *Muscular Motion* is most likely to be produced by some subtile volatile Matter flying from the Nerves into the muscular Fibres, and increase-
ing

ing the attractive Quality of their component Particles towards each other, so as to make them run nearer together, which will consequently occasion the Coats of the Fibres to be both thicker and shorter; I say, If we should endeavour to maintain such a Thing as this, I hope it will not appear very irrational, since it is only comparing it to the well known and constant Effects of all volatile, subtile, and pungent Particles on the Fibres of an animal Body.

THE immediate and wonderful Efficacy that Spirits of Salt Armoniac, Hartshorn, or human Skulls have on the Body, makes it probable that all animal Motion arises from the Influence of some refined Matter near akin or analogous to these Spirits: And that the Nerves are always replete with some such volatile Spirituous Matter, or animal Spirits, I shall now, in the Vth Place, prove to be more than probable.

I AM very sensible that many learned Men have denied the Existence of animal Spirits, because they are not within the Reach of our Senses;

Senses; that is, when a Nerve is tied up, no Swelling appears either above or below the Ligature; or if a Nerve be cut asunder, only a little viscid mucilaginous Juice flows from it, which by no means can be thought sufficient to perform the chief Office in *Muscular Motion*: But if we diligently examine into the most wonderful Mechanism and Structure of the Brain and Nerves, (those Master-pieces of the Creation) I am persuaded there will be a vast deal more to be said in Favour of the Existence of animal Spirits, than against it, though at the same time we are not capable of discovering such subtle Matter by our Sight, Smell, &c. however assisted.

ALL Anatomists agree, that the Brain is an Heap of exceeding minute Glands, wrapt up in two nervous Membranes, the *Dura* and *Pia Mater*; and the Nerves, which arise from it, are also allowed to be its excretory Ducts. Now since all the known Glands have so much Resemblance, Similitude, and Analogy to one another; is it reasonable to suppose that such an infinite Number of Glands, as the Brain is composed

posed of, do act contrary to the Nature of all the rest in the Body, and not secrete any Thing from the Blood? If they do separate or filtre any Thing from the Blood; pray, what becomes of it? That poor Pittance of viscous Juice, which is to be squeezed out of a Nerve, upon Excision, does not seem at all agreeable to the Office of so many and such exquisitely fine Glands, from whence the nervous Cord arises. But because all our Inventions are short of discovering the subtile Matter which continually flies through the Nerves; it must therefore follow, according to these *Gentlemen*, that no such Matter does fly through them. By the same way of Arguing, we may deny that any subtile Matter flies from the Loadstone, or from many volatile Bodies, because we can't see or discover what it is, or its manner of acting. Let us but think on some of the Experiments which are commonly made to discover the wonderful and amazing Divisibility of Matter; and it will evidently appear from thence, that the Nerves may always be replete with animal Spirits, which are too subtile ever

H

to

to be discovered by our shallow Capacities, but by their Effects on the Muscles, &c.

AGAIN: What has been said, may be illustrated by observing, that the Brain receives a much greater Proportion of Blood, than most other Parts of the Body of like Dimension, so that a Quantity equal to the whole Mass of Blood circulates through it in a very little Time; and the Aliment, from whence the Blood is supplied, is generally such as will afford a good deal of the most volatile, subtile, and spirituous Matter; as is evident from many chymical Processes on animal and vegetable Substances, and also on fermented Liquors: And it must be allowed, that the Brain is the most likely Part of the Body to secrete such volatile spirituous Matter; because its constituent Vessels are by far the finest of any, and are infinitely ramified beyond any Idea we can possibly form of them.

THE Structure of the Nerves, also confirms me in my Opinion, that they were designed, by the

the Divine *Architect*, to convey some very subtile and spirituous Matter through them; their Coats being made so firm and solid, in order to prevent its Escape, before it arrives at their Extremities.

OUR best *Anatomists* are also of this Opinion.

“ The Nerves (says Mr. CHESELDEN, in his
“ excellent Book of *Anatomy*) seem, when
“ examin’d with a Microscope, to be Bundles of
“ strait Fibres not communicating with one
“ another: And I am inclined to think, that
“ every the minurest Nerve, terminating in any
“ Part, is a distinct Cord from its Origin in the
“ Brain, or Spinal Marrow; or else I don’t see
“ how they could produce distinct Sensations in
“ every Part: And the distinct Points of Sen-
“ sation throughout the Body are so very nu-
“ merous, that the whole Body of Nerves (which,
“ taken together, would not make a Cord of an
“ Inch Diameter) must be divided into such a
“ Number, to afford one for every Part that has
“ a distinct Sensation, that surely such a Nerve

" would be too small to be seen by the best
" Microscope."

AND again, (the same ingenious *Author*
tells us) " Diligent Enquiry has been made,
" to discover the Cavities of the Nerves, but
" hitherto in vain: And if each Nerve is distinct
" from its Origin, and too small to be the Object
" of the best Microscope, I don't see how such
" Cavities are like to be discovered. However,
" I think the Nerves may be Tubes; and that a
" Fluid, whose Cohesion is very little, and whose
" Parts are perhaps no finer than Light, may
" move very freely in them."

THE learned *Author* of the *Introduction* to
Cowper on the *Muscles*, observes, " That the
" Nerve is one chief Instrument which puts the
" Muscle into Action; as is evident from hence,
" that whenever the Nerve belonging to a Muscle
" is separated from it, it is no longer in the
" Power of the Animal to put the Muscle into
" Action. This Office of the Nerve is generally
" allowed

" allowed to be performed by means of some
 " very fine and subtile Fluid, which is called by
 " Authors the Animal Spirits; and that the
 " Contraction of the Muscles concerned in volun-
 " tary Motion, arises from this Spirit being some
 " way operated upon at the Original of the
 " Nerves. All which seems evident from this
 " Observation, that a Ligature upon the Nerve,
 " deprives the Muscle of its Motion, as effec-
 " tually, as if the Nerve were divided.

IF we go back as far as GALEN †, he tells
 us, *Nervorum Utilitas est Facultatem Sensus &
 Motus à Principio in Partes diducere.* And
 Dr. CHARLETON, in his *Enquiries into Human
 Nature*, takes Notice of another Observation of
 GALEN'S: " GALEN (says he) reflecting upon
 " this, that if a Nerve be cut asunder, the Muscle
 " into which it was inserted, becomes ever after
 " incapable of being used to voluntary Motion;
 " from thence, with great Assurance, concludes;
 " *Nervi igitur, Rivorum in Morem, à Cerebro*

† De Usa Partium

" *ceu ex quodam Fonte, deducunt Musculis Vires.*
 " Where 'tis remarkable, that he compares the
 " Nerves, not to Strings or Cords, but to
 " Rivulets or Conduit Pipes; framed for the
 " Conveyance of the invigorating Influence, or
 " *πρωτη Ορμη* (as he calls it) *first Impetus*, from
 " the Brain, as from a Fountain. And what
 " could he have said, either more intelligible in
 " itself, or more favourable to the Doctrine of
 " Animal Spirits?

IN short; If we deny the Existence of animal
 Spirits, I can't conceive it possible to give a ra-
 tional Account of *Muscular Motion*: For though
 the Nerves are very elastic Cords, when they
 are stretched out longer than usual, and by this
 means, some have thought they may be capable
 of vibrating in such a manner, that both *Sensation*
 and *Muscular Motion* may be perform'd by them,
 without the Assistance of animal Spirits; yet if
 we consider, that they are by no means extended
 or contracted in their natural State, but lie very
 loose and slack, it seems impossible for them
 to communicate Motion, from the common
 Senso-

Sensorium in the Brain, to the most distant Muscles, in an Instant. But supposing the Nerves, in their natural State, were tense enough to vibrate with the most inconceivable Swiftneſs, from one End to the other, I deſy any one to ſhew, that a vibrating Motion in the Nerves, is the only and true Cauſe of Contraction in the muscular Fibres; it being evident, from the ſecond Law of Nature, that the Motion of any Body is always proportional to the impreſſed moving Force, and is produced in the ſame Direction with that of the moving Force. From whence it appears, that a vibratory Motion in one String, can only impart the ſame ſort of Motion to another; but *Muscular Motion* ariſes from ſomething which thickens the Fibres, purſes them up, and ſhortens their Length.

WE have been lately told indeed, by a very learned Author, † That *Muscular Motion* is perform'd by the Vibrations of a very elastic Æther, lodged in the Nerves and Membranes inveſting the minute Fibres of the Muſcles; and that this Æther is capable of the moſt ſudden Expansion from the leaſt Impulſe communicated to it; by which means it inſtantly diſtends and ſwells the Membranes, and contracts the Fibres. But, in my humble Opinion, this Hypotheſis is far from being ſatisfactory; it being abſolutely im-

† Dr. Bryan Robinſon's Treatiſe of the Animal Economy.

possible for the Membranes to be blown up by any Agent whatever, so as to contract the Fibres which they invest : For, supposing them to be inflated by the expansive Force of an included Æther, yet no such Effect could follow as shortning the Fibres ; because as the Membranes are soft, and equally yielding every way, and the expanding Æther pressing *undiquaque*, it is evident that the Membranes must be proportionally enlarged in all their Dimensions *, and consequently *Muscular Motion* cannot be performed after this manner.

As to those who imagin *Muscular Motion* may be performed by Vibrations in the Nerves themselves, the following Difficulties will always attend their Supposition.

1st, SINCE every visble nervous Cord is allowed to be a *Fasciculus* of exceeding minute Nerves tied up close together by a Coat or Membrane derived from the *Dura* and *Pia Mater*, and as these *Capillamenta* are afterwards infinitely dispersed to various and different Muscles ; it follows from hence, that *Muscular Motion* could not be distinct, if it arose from a Vibration begun at the Origin of the nervous Cord : For, in such a

* Dr. Morgan's Phil. Princ. of Medicine.

Case, the vibrating Motion must be communicated to all the *Capillamenta* contained in that Cord; unless it can be proved, that one Thread in a Cord may vibrate with the greatest Swiftness, from one End to the other, without imparting any of its Motion to the others which are closely connected to it: And this, I believe, is a Task that not many will undertake.

2^{dly}, IT does not seem agreeable to those sublime Speculations which Mr. LOCKE and Others have made, concerning the Soul, to think that it is capable of giving so great an Impulse to the Origin of a nervous Cord, as to vibrate so solid a Substance with such prodigious Velocity as *Muscular Motion* is well known to be performed, after it is once determined by the Will. Indeed, how the Soul or Thought influences Matter, is past our Comprehension: but it is most natural to believe, that it acts only on the most subtile, rare, and elastic *Aura* in the Body, or, as we may call it, the very Ending of Matter.

BUT

BUT to avoid Prolixity : These, and many more, are the Difficulties which attend an Hypothesis founded on the Vibration of the Nerves ; whereas if it be granted, that the Nerves are always replete with animal Spirits, it will follow, that the least imaginable *Impetus* will be sufficient to communicate an undulating Motion to them ; and an Undulation in such refined Matter as the animal Spirits are supposed to consist of, may fly through a nervous Fibril, without impressing so much Motion to its Coats, as to disturb its neighbouring *Capillamenta*. For though it is most certain, that there must be some Friction in the nervous Tubes, from the Motion of the animal Spirits through them, let them be ever-so rare and subtile ; yet if we consider that the Middle of every Nerve seems to be a sort of *Medulla*, derived from the Brain, and that this is soft, spongy, supple, and unelastic, it will appear, that the Spirits may undulate through this medullary Substance, without imparting such Motion to the Membranes of the Fibril, as will vibrate its adjacent *Capillamenta*,
though

though they are ever-so closely connected together.

'Tis true, there are some Instances which, upon a superficial View, look as if the Nerves were design'd by Nature to have a free Communication or Consent with each other, in order for their mutual Security. As for Instance : When any acrid irritating Substance stimulates the Expansion of the olfactory Nerves, the phrenic and intercostal Nerves are soon affected, so as to produce that violent convulsive Motion *Sneezing* ; by which means the offending Matter is often cast out of the Nose, and all is easy. The same Sympathy is observed between the Nerves of the Kidneys and Stomach, and between many others, when their Expansions are violently contracted or distracted ; at which time the Pain is always very great, and the Mind grievously afflicted with it : So that even these Effects cannot be properly attributed to a vibratory Motion communicated from one Nerve to another ; because 'tis evident, that the Idea's of Tickling or Pain are always impressed on the *Sensorium* in the Brain,

Brain, before their Effects, viz. Sneezing, Vomiting, or any other convulsive Motions arise : And if the *Sensorium* is always first affected, it is most natural to believe that the Soul or Mind influences such and such particular Parts to expell the Enemy, rather than a vibratory Motion being communicated from one Nerve to another.

If I had Time to examine into the Nature of Sensation, it might, perhaps, illustrate what has been said ; but that would be going beyond the Bounds I have set myself ; and therefore I'll content myself with making but one Observation ; viz. If the Sole of the Foot be touched only with the Down of a Feather, and in the most easy and gentle manner imaginable, the Idea of Tickling is instantly communicated from thence to the *Sensorium* in the Brain. Now 'tis beyond the Bounds of my Philosophy to comprehend how so small an *Impetus* on the Nerves, can possibly raise a Vibration in such slack Cords, quick enough to impress the Idea of Tickling on the *Sensorium* in an Instant. 'Tis true, the first Impression must be made on the *Papilla Pyramidales*,

midales, or on the Extremities of the Nerves, by the Feather, and from thence it is imparted to the animal Spirits within the Nerves, so that the undulating Motion of the animal Spirits is in some measure the Effect of the Motion of the Nerves; but then, I presume, the least Motion impressed on the most subtle, elastic, animal Spirits will not cease 'till it arrives at the *Sensorium* of the Brain; whereas so slight a Motion communicated to a slack solid Substance must be immediately lost, and, as it were, absorb'd in the Flesh, which almost every-where surrounds the Nerves. Besides, if we consider that the Nerves which are tickled at the Bottom of the Foot, arise either from the three last Pair of the lumbal Nerves, or from the three or four first Pair of the *Os Sacrum*, it will appear that the strongest vibratory Motion in these Nerves cannot be communicated beyond that Part of the *Medulla Spinalis* from whence they have their Origin: For the medullary Part of the spinal Marrow being very soft, yielding, and unelastic, and its Coats, which are elastic, being very firmly tied to the *Vertebrae*, by means of the inward vertebral Membrane, and thirty

Pair

Pair of Nerves which proceed from it, makes it impossible for a vibrating Motion in the crural Nerves to impress any Idea on the *Sensorium*, if it was not for some other Assistant.

WHERE the nervous Fibrils conjoin into one *Fasciculus*, there are formed some knotty oval Bodies, called by FALLOPPIUS, *Corpora Olivaria*, and generally now named *Ganglions*, whose Use or Design has not yet been hit on, at least not satisfactorily : But if I may be allowed a Conjecture upon so intricate a Subject, I think it probable that they are designed to prevent any Communication of Motion from one Nerve to another, whereby Sensation is always, in a State of Health, perform'd distinctly. As for Instance : When a more violent Shock than ordinary is given to the Extremity of a Nerve, it can't be denied but the Nerve itself, as well as the animal Spirits within it, may be put into a *Tremor*, more or less, according to the Tension of the nervous Fibril ; and though the greatest *Tremor* may not be capable of reaching the *Sensorium* itself, yet if it was to continue nearly with the same Force
after

after the Nerve is conjoined with others, it must follow of Course, that the vibratory Motion would be imparted to the adjacent *Capillamenta*, from whence the animal Spirits within them would receive the same sort of Motion as was impressed on the first Nerve; and if so, there must necessarily arise such a Confusion of Idea's as the *Tremor* of all the *Fibrillæ* in that nervous Cord, would represent on the *Sensarium* in the Brain.

SINCE therefore the *Ganglions* are generally formed, more or less, where-ever the nervous *Capillamenta* meet together, and since these Knots are frequently repeated; it appears, at least to me, that they may entirely intercept any vibrating Motion which may happen in the Nerves: For as these Knots are strong and thick, or, as WILLIS observes, they grow out into a certain Tumour like to a callous or sinewy-swelled Body, and as they are only fasten'd to the Coats of the Nerves, whilst the middle or medullary Part of the Nerves passes through without any Alteration or Change; it follows, that such a Check may be given to any *Tremor* in the nervous Coats, as to prevent its

its being communicated any farther; whereas the undulating Motion of the most subtile Matter in the Nerves is not interrupted in the least by these *Ganglions*, but flies through them to the *Sensorium*, and there impresses its proper Idea.

WHEN I contemplate on this most wonderful Mechanism of the Nerves; that every Part of the Body has a particular Sensation; that each sensitive Part has its corresponding Point of Perception in the Brain; that such an infinite Number of nervous Filaments, as are dispersed to every individual Part of the Body, are collected into forty Pair of Cords; that every Fibril in these nervous Cords is endued with a Power of impressing the Ideas of Pleasure or Pain on the *Sensorium* in the Brain, as well as transmitting the subtile Influence from the Brain to the Muscles, and that both *Sensation* and *Muscular Motion* are always, in a State of Health, performed distinctly; I say, when I meditate on these Things, I am lost, as it were, in a Labyrinth of Thought, and can only admire the infinite Wisdom

Wisdom of the *Great Creator*, who hath thus fearfully and wonderfully made us.

By this time I hope I have made it appear to be more than probable, that there is some most subtile, volatile, spirituous Matter secreted from the Blood, by the Glands of the Brain, and continually flying into the Nerves; and upon this *Data*, I proceed,

Vltbly, To make some few Observations on the Muscles, during their State of Contraction, in order to illustrate more clearly the genuine Cause of it.

1st. IT is evidently demonstrated by the following Experiment of Dr. GLISSON, † that the Muscles are not inflated, expanded, or enlarged when they are contracted; that is, though the Belly of a Muscle may swell a little during its State of Contraction, yet the Bulk of the Muscle in general, is rather less than it was before :

† De Ventric. & Intestin. Cap. 8. Numer. 9.

“ LET there be provided a Glass Tube, in
“ Length and Bore capacious enough to hold
“ a Man's Arm, and to the upper Orifice of it
“ on the Outside affix another Tube of Glass
“ about an Inch Diameter in Bore, shaped like
“ a common Weather-glass, only with a wide
“ Mouth like a Funnel; so as the Lower-end
“ may open into the greater Tube whose Bottom
“ is firmly stoppt: Then having erected both
“ Tubes, let a Man of strong and brawny
“ Muscles thrust his whole naked Arm into the
“ greater Tube up to the very Shoulder, about
“ which the Orifice of the Glass must be closely
“ luted, that no Water may flow out that way.
“ This done, let as much Water be poured in
“ by the Tunnel as both Glasses will receive,
“ leaving only a little Space at the Top of the
“ lesser, empty. In fine, let the Man strongly
“ contract all the Muscles of his Arm by
“ clinching his Fist, and relax them again by
“ Turns; and you shall observe, that when he
“ contracts his Muscles, the Water in the less
“ Tube will sink somewhat lower, but rise
“ again

“ again when he relaxes them : Whence it is
 “ evident, that the Muscles do not swell up, nor
 “ are inflated at the time of their Contraction,
 “ but rather are lessened and contracted in all
 “ their three Dimensions ; otherwise the Water
 “ would at that time, not descend, but ascend
 “ in the Neck of the Funnel.”

2^{dly}, NOTWITHSTANDING it is demonstrated,
 by the foregoing Experiment, that the Bulk of a
 Muscle is rather lessened than enlarged, during its
 Contraction ; it is as evident, that every single
 Fibre must necessarily increase in its Thickness
 proportionally as it abates in its Length.

3^{dly}, HENCE appears the Reason why the
 Belly of a Muscle swells during its Contraction :
 For as the component Particles of each Fibre are
 more loosely joined together about the Middle,
 than towards its Extremities, which are generally
 tendinous, it is natural to suppose that the chief
 Action is between them ; that is, when a Fibre
 grows shorter, its Particles which are most at
 liberty must run nearer together, or slip by one

another ; and as the Motion of all Bodies is ever in Proportion to the Impulse and Resistance they meet with ; so when the constituent Particles of the muscular Fibres are drawn into a shorter Compass, by any impressed Power, the Fibres must swell either inwardly or outwardly, or both, according to the Resistances they meet with.

4thly, SINCE the Coats of the muscular Fibres do most certainly grow thicker as they contract in their Length, and the external Surface of the Muscle in general is diminished thereby ; it follows from hence, that their Cavities must grow less, and their contained Fluids must be pressed out in Proportion to the Contraction of the Muscle.

NOW from these Observations, I think, there is great Reason to conclude that *Muscular Motion* arises from the Influence of the animal Spirits which instantly increase the Strength of the corpuscular Attraction in the Fibres themselves, so as to make their constituent Particles run closer together, or, as it were, up into Heaps, as long as
such

such an additional attractive Power remains in the Fibres. And if we look back and consider that the Elasticity of a muscular Fibre is owing to the mutual Attraction of its component Particles; that its Tension proceeds from a constant *Nisus* towards Contraction; and that not only these, but the Contraction of all the Muscles, are well known to be made more vigorous and strong, by the Use of such Things which consist of the most volatile and subtile Particles, the Thing itself will appear more plainly.

THAT the animal Spirits are capable of answering all the Requisites towards *Muscular Motion*, will appear from the following Considerations. 1st, They are generally allowed to consist of Matter the most refined and most agile of any in the Body; as subtile, perhaps, as the Particles of Light, or *Des CARTES's Subtilis Materia*; and if so, their Velocity may be equal to that of Lightning, and consequently voluntary Motion may be instantaneous. 2^{dly}, The animal Spirits, being extreamly subtile, are capable of insinuating themselves into the least Interstices
between

between the constituent Particles of the muscular Fibres. 3^{dly}, As they consist of the smallest Particles of any in the Body, their attractive Power is the greatest, as is evident from what Sir ISAAC NEWTON has calculated concerning the Rays of Light. And, *lastly*, The animal Spirits being so exceeding subtile, they cannot be fixed, and consequently they will immediately make their Escape through the muscular Fibres, and leave them in the same State they found them in, as soon as the Supply from the Nerves is by any means discontinued.

THESE Things being granted us, our next Task will be, To shew upon what Mechanism it depends, that some of the Nerves and Muscles are disposed to produce voluntary, and others involuntary Motion; and this we will endeavour to do in as easy and perspicuous a manner as the Nature of the Subject will admit of.

THE voluntary Muscles are such as are never contracted, in a State of Health, but by the Direction of the Will or Mind: From whence it
evidently

evidently appears, that the Nerves which supply the voluntary Muscles with animal Spirits, have some little Constrictions at their Extremities, or elsewhere, which the ordinary Impulse of the animal Spirits is not capable of removing, but when they are under the Direction of the Will; that is, whenever it is our Pleasure to contract such and such Muscles, the Will directs or propels a greater Quantity of Spirits, or the same Quantity with a greater Force, into the Nerves which go to those Muscles; and by this Means the Constrictions are overpowered, and the animal Spirits flow freely into every Fibre of the Muscle or Muscles to be contracted.

By the Influence of the animal Spirits on the component Particles of the Fibres, they will be more strongly attracted towards each other, and from thence the Fibres will necessarily shrink up, contract, and run closer together; and thus it continues as long as we please, or as long as we are able to direct such a Quantity of animal Spirits to the same Muscles; for 'tis evident, we are not capable of keeping any of the
voluntary

voluntary Muscles in a constant State of Contraction.

THAT the Nerves, which supply the voluntary Muscles, have a Power of denying a Passage to the animal Spirits into the muscular Fibres at all other times but when they receive an additional Impulse from the Will, is plain ; because whenever these very Nerves happen to lose their resisting Force, the voluntary Muscles immediately become involuntary ones, and they are alternately contracted and relaxed without the Consent or Direction of the Mind ; and from hence arises a Distemper commonly call'd a *Shaking Palsy*.

THE Muscles being contracted meerly by the Influence of the animal Spirits, and the Influx of the Spirits being stop'd, by withdrawing the *Impetus* given to them from the Will, the Reason and Manner of their Relaxation will easily appear : For as the animal Spirits are most extreamly subtile, that Portion of them which is thrown into the muscular Fibres acts but for a Moment, or the least Space of Time ; and no sooner is the
Vigour

Vigour of the Attraction over, but the Tension of their Antagonists, and the Impulse of the circulating Blood, will extend them again.

NOW let no One be surprized at our attributing so much Subtilty and Activity to the animal Spirits, that *Muscular Motion* may be produced by them in an Instant, and made to cease again in another Instant : For if we consider how instantaneously the *Effluvia* of a Loadstone affect the Filings of Iron laid on a Table ; that it will make them all stand upright in a Moment, and if you withdraw the Stone, or intercept the *Effluvia* with an Iron Plate, that these Effects cease as soon ; or if we consider that even the *Effluvia* of Glass are so subtile, that when a Glass Tube is well rubbed, it will communicate an attractive Virtue to an Ivory Ball at eight hundred eighty-six Feet Distance, by the means of a Packthread only, so that the Ivory Ball, at the End of the Packthread, will strongly attract Leaf Brass at some Inches Distance, and make it suddenly leap up to it, and fall from it again, (as the ingenious Mr. STEPHEN GRAY has inform'd us,

in several of the *Philosophical Transactions*); I say, If we consider that these Things are demonstratively true, it may easily be conceived that the animal Spirits are capable of performing *Muscular Motion* after the manner we have here described,

THUS much for Voluntary Motion: And as to the Involuntary Muscles, I don't know of any which may be truly and properly so called, unless it be those of the Heart. For though we are always under a Necessity of alternately contracting and dilating the intercostal Muscles and Diaphragm; yet these are evidently subject, in some measure, to the Will; because we can contract them faster or slower just as we please, and keep them in a State of Contraction, or Relaxation, as long as the want of Inspiration or Expiration will admit of.

THE Sphincter Muscles, which are thought by some People to be always in a State of Contraction, seem to me to be no otherwise so, than what one may properly call a State of Tension, by

by which means those of the *Anus* and *Vesica Urinaria* prevent the involuntary Effusion of their Contents. Nothing is more evident than that it is always in our Power to contract these Muscles more than ordinary : For let a Man compress his Bowels or Bladder ever-so much, by contracting the Diaphragm, abdominal Muscles, &c. yet if he has a mind to contract the Sphincters of the *Anus* and *Vesica Urinaria* at the same time, the other Powers will not be able to overcome their Resistances, notwithstanding, perhaps, twice the Force is applied to them as is usual in going to Stool, or in making Water.

THE Sphincter *Vaginae* is also under the Command of the Will ; and the Sphincter *Oris* is so much a voluntary Muscle, that it need only be mention'd. But not to dispute any longer about which are involuntary Muscles, and which are not, let us proceed to account for the involuntary Motion of the Heart, which we are very sure is so.

THE Heart is a *Viscus* which has already given the Learned a deal of Trouble to find out its real Mechanism, and the immediate Cause of its regular Alternations of Contraction and Dilation. The incomparable Dr. LOWER † was the first that gave us a true mechanical Description of the Structure of the Heart, and the Manner of its Action; and though his Hypothesis of the Cause of Contraction in the muscular Fibres is wrong, yet he has shewn us that the *Systole* depends upon the same Agent that influences all the other Muscles, viz. the animal Spirits; and if he had given as rational an Account of the *Diastole*, he had left us but little Room for farther Enquiries: but to say that the *Diastole* arises from a Motion of Restitution, and the Influx of the Blood, without producing any Proofs of it, or even shewing the Possibility of it, is saying Nothing, at least, not to the Purpose.

† De Corde.

Mr. COWPER, || observing how transiently Dr. LOWER passed over this most important Affair, expatiates more largely upon it, and endeavours to prove, that the Motion of the reflux Blood is a sufficient *Momentum* to dilate the Heart, and to overpower its contractile State or *Systole*, which, he imagines at the same time, to be its natural State of Rest or Quiescence, and to which it always tends. But notwithstanding this ingenious *Gentleman* has taken more Pains to prove the Thing, yet if we accurately and attentively examine into the Nature of it, it will evidently appear that neither the *Pondus* nor Impulse which the Blood receives from the Constriction of the Heart, can ever be able of itself to overpower the contractile Force of the Heart: For (as Dr. DRAKE † observes) could the Blood be suppos'd to re-act upon the Heart, with all the Force first impressed upon it by the Heart, it would be insufficient; unless we will suppose the

|| Anatomy of the Human Body.

† Phil. Transact. N^o 280.

Force communicated to be superior to the Power communicant ; which is absurd, and repugnant to the known Laws of Nature.

Now though Dr. DRAKE has sufficiently refuted these Sentiments of Dr. LOWER, and Mr. COWPER, and has demonstrated that there must be some other Agent, yet undiscovered, in order to dilate the Heart ; I am humbly of Opinion that the Hypothesis which he has advanced concerning it, is as liable to Objections as any Thing I have met with.

“ WHATEVER the Force is (says He) that
“ dilates the Heart, and is the Cause of the
“ *Diastole*, it must be equal to that of the
“ Heart, the intercostal Muscles, and Diaphragm ;
“ to all which it acts as an Antagonist. Now
“ such a Power is not to be found within the
“ Body, and therefore some external Cause must
“ be found to produce this great Phanomenon ;
“ which Cause must be either in the Air or Atmos-
“ phere, because we have no constant and imme-
“ diate Commerce with any other *Media*. By the
Pressure

“ Pressure of the Air in the Lungs the Blood is
“ forcibly driven, as it were with an *Embolus*,
“ through the Pulmonary Vein into the left Ven-
“ tricle of the Heart ; and this, together with
“ the general Compression of the Body by the
“ Weight of the Atmosphere, which surrounds
“ and presses upon the whole Surface of it, is
“ that Power which causes the Blood to mount
“ in the Veins, after the Force impressed upon it
“ by the Heart is broken and spent, and which
“ is sufficient to force the Heart from its natural
“ State (of Contraction) to Dilatation.”

THAT the Pressure of the super-incumbent Air on the Surface of the Body is very great, is manifest from many Experiments publish'd by Mr. BOYLE, and Others ; and that Respiration contributes very largely towards the Circulation of the Blood, cannot be denied : but that such Force is communicated to the reflux Blood by either of these, as to exceed the contractile Strength of the Heart, is only asserted by the *Doctor*, without producing one Experiment to confirm the Truth of it. Before such a strange Conclusion as this

this had been made, I think, it should have been proved that the Blood returns to the Heart with a greater Velocity than it left it; otherwise it is absolutely impossible for it to overpower the Constriction of the Heart, if that be, as the *Doctor* says, its natural State of Quiescence to which it always tends.

IF the Pressure of the Air gave such Assistance to the Motion of the refluxent Blood, it might easily be discovered by opening the Veins near the Heart; for in such a Case the Blood would stream out of them with a greater Arch than it would out of the Arteries: But as Autopsy entirely contradicts this, 'tis unreasonable to suppose that the refluxent Blood is capable of dilating the Heart, if its Contraction after the Blood is forced out of it, was to continue with the same Strength as before.

'Tis almost needless to take notice that the Pressure of the Air on the external Surface of the Body, is an Antagonist to the Elasticity of the internal Air, or the Air which is contained with
the

the Fluids, and in all the Cavities of the Body ; and that by the Action and Re-action of these Powers an Equilibrium is preserved, and the Circulation is carried on regularly : whereas if either of these Powers was to be taken off, the other would immediately put a Stop to all Motion ; the former would condense the Fluids, and press the Vessels as it were flat, and the latter would rarify the Fluids so as to distend and tear the most tender Canals to Pieces.

THE Air, being a Fluid, presses *undiquaque* ; and there being always an exact Equilibrium between the external and internal Air, the Pressure of the Air on the Surface of Body must retard the Motion of the Blood in some of the Vessels, as well as promote it in others. Indeed, in the Lungs, where their superficial Dimensions are variable, by their reciprocal Dilatation and Contraction, the Pressure of the Air has a vast Influence : but even there I defy any one to prove that the Blood returns to the Heart thro' the Pulmonary Vein, with as great Velocity as it was
M thrown

thrown out of it into the Pulmonary Artery ; and if it does not, I can't conceive how such an Effect, as above mentioned, could be attributed to it.

BUT granting the Action of the Lungs to be the sole Cause of the Diastole of the left Ventricle of the Heart, how shall we infer from thence the Cause of the Dilatation of the right Ventricle ? For if the Pressure of the Air on the Surface of the Body was able to increase the Momentum of the Blood in both the Cava's, so as to overpower the Resistance of the right Ventricle of the Heart, it would necessarily follow that the right Ventricle would ever afterwards remain in a State of Dilatation ; because the Pressure of the Air being constant and equal on the Surface of the Body, (allowing for the different Heights of the Mercury in the Barometer, its Effects must be so too ; and this, of itself, is sufficient to detect the Falsity of such an Hypothesis.

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SINCE therefore so many fruitless Attempts have been made to account for the Diastole of the Heart, by supposing the Systole to be its natural State of Rest or Quiescence, to which it always tends with its utmost Force; 'tis more than probable that the *Literati* have been deceived in this Assertion, and that there is some peculiar Mechanism or Structure in the Heart itself which is the Occasion of all this, without seeking so far for Assistants, or lugging in such as are quite inconsistent with the animal Oeconomy. I shall therefore, instead of amusing myself any longer with what has been said by others, consider attentively the *Phænomena* which have fallen under my Observation, concerning the Action of the Heart, and then deliver, in as plain a manner as possible, what my own Thoughts have suggested to me on this most intricate Affair.

THE first Thing to be taken notice of, is, that the Systole and Diastole of the Heart and its Auricles regularly and alternately follow each other; that is, the Auricles are contracted when

the Ventricles are dilated, and the Ventricles contracted when the Auricles are dilated. I have oftentimes laid open the Breast of a Dog, and kept his Lungs playing with a Pair of Bellows, in order to observe this compound Motion of the Heart, and always found that the Moment the Ventricles were contracted, the Auricles were dilated by the reflux Blood, and then, they, in their Turn, contracted, and propelled the Blood into the Ventricles; so that the Auricles evidently act as Antagonists to the Ventricles, and the reflux Blood is of the same Service to the Auricles: But as there is so much Disparity between the contractile Strength of the Ventricles and that of the Auricles, there must necessarily be some particular Contrivance in this Machine, which, as soon as it is fully contracted, makes itself unbend again, or cease to contract; by which means the Auricles, though weak in Comparison to the Ventricles, have Power enough to dilate the Ventricles to such a Pitch before they are capable of acting again. The same Thing may be said of the Auricles; for as the Reflux of the Blood is steady and equal, the Pressure on the Auricles must

must be so too ; and as the Auricles are strong enough to contract themselves, notwithstanding the constant Impulse of the Blood, it naturally follows, that if they did not relax of their own accord, the Pressure of the reflux Blood would not be able to overcome them.

WITHOUT some such Mechanism as this, it plainly appears from what has been said, that no Power yet known, either within or without the Body, would be able to dilate the Heart ; and therefore I beg Leave to prosecute this Thought, and try if I can't make it agreeable to some other *Phænomena* which frequently happen in the animal Oeconomy.

IN all hydraulic Engines there is an absolute Necessity for a perpetual Supply of the moving Force, though it may not always act on the same Part of the Machine, especially if it be a compound one, but sometimes on one Wheel, and sometimes on another, according as the Springs and Movements are disposed to receive the same.

THUS

THUS I believe it to be with the Heart, and its Auricles, whose alternate Motions, being mechanically performed, doubtless arise from an alternate Influence of the animal Spirits on their muscular Fibres ; but to illustrate this most excellent Piece of Machinery, and to shew the Manner of its Action, from such Principles, is the Difficulty : However, I'll not despair, but venture to suppose (it being beyond the Reach of ocular Demonstration) that the Nerves which supply the Heart and its Auricles are always open ; that is, they have no Constrictions at their Extremities or elsewhere, as those of the voluntary Muscles have, but admit the animal Spirits to fly from the Brain into the muscular Fibres of the Heart and its Auricles without any Lett or Impediment, or without any Impulse or Assistance from the Will.

THIS being the Case, the Ventricles of the Heart will be first of all contracted, by reason of their superior Power ; and during their Contraction, it appears, from what has been said above,

above, that every individual Fibre in them will be corrugated, thicken'd, and swelled by the Influence of the animal Spirits : And now if we consider how strong and uniform the Pressure of these Fibres must be upon the Blood in the Ventricles, before it can propell it with so much Velocity, and in how many different Directions the Fibres run in, it will not be at all unreasonable to think that the Extremities of the Nerves, which are inserted into every Fibre, and are extremely small and tender, may be pressed upon and squeezed during the violent Action of the Heart, and the Re-action of the Blood, so as to prevent the Influx of any more animal Spirits 'till the Pressure is abated, or 'till the muscular Fibres are relaxed and dilated again.

THE Influx of the animal Spirits being obstructed when the muscular Fibres of the Heart are in their State of Contraction, and the animal Spirits being extremely volatile, the Vigour of the Attraction between the constituent Particles of the Fibres will instantly cease, and the Ventricles will stand in need of some proper Assistant

to dilate them again to their usual Size; and to take off all the Pressure and Obstructions from the Extremities of the Nerves; that is, before the animal Spirits can have a free and uninterrupted Passage into the muscular Fibres again, the Fibres must be extended to their usual Lengths.

NOW this friendly Office is no sooner wanted but performed by the successive Contraction of the Auricles, which are now strong enough to propell the Blood into the Ventricles, to dilate their relaxed Fibres, to take off all Obstructions, and to make Way for the animal Spirits to fly into every minute Fibre again; which no sooner happens, but there succeeds another Contraction and Dilatation of the Ventricles, as described above.

HENCE it appears, that when the Heart is contracted, the Manner of its own Motion prevents a Continuance of it; and without some such Mechanism, 'tis evident that neither the Strength of the Auricles, nor the Pondus of the reffluent Blood, nor the Pressure of the Air, nor
any

any Thing else which we are able to discover, would be sufficient to dilate the Ventracles of the Heart, if the same attractive invigorating Influence was always to act with a constant, equal, and regular Force on their muscular Fibres; so that, in all Probability, this is a true and real Description of the Action of the Heart, both as to its Systole and Diastole.

THE same Contrivance will account for the alternate Contraction and Dilatation of the Auricles; because the constant Pressure of the reflux Blood is of the same Use towards extending their muscular Fibres, after their Contraction, as the Impulse of the Blood in the Ventracles is from the Contraction of the Auricles.

If Time would permit it, we might here expatiate very largely on the Beauties and Excellencies of the whole Piece of Machinery; which is so admirably contrived, that the Impulse given from one Part, always begets Motion in another, That on the next, and so on throughout the whole Body. From the Circulation of

the Blood, the Being and Motion of the animal Spirits are derived ; from the Influence of the animal Spirits over the muscular Fibres, arises all manner of *Muscular Motion* ; from *Muscular Motion*, the Circulation of the Fluids is maintained ; and from the Circulation of the Fluids, all the Vessels are kept warm, supple, distended, and every way ready for Motion : but how the *Primum Mobile* or *First Impetus* is given, is beyond the Reach of our frail Capacities to conceive.

THIS is my Theory of *Muscular Motion*, which I have deduced from a very uniform, simple, and beautiful Structure of the Nerves and muscular Fibres, and from the commonly-known Laws of Matter and Motion ; and since it appears, from all the Discoveries which have hitherto been made, that Nature takes the most easy Course in all its Productions ; it follows, that whenever we would investigate or trace out any of the secret Footsteps of Nature, it must always be done by the most simple and uncompounded Means, by deriving two or three general Principles

Principles from *Phænomena*, and afterwards by shewing how the Properties and Actions of other Bodies follow from those manifest Principles, though, at the same time, the Causes of those Principles are not yet discovered.

THIS is the Case in Hand : Attraction and Repulsion are Principles manifestly belonging to Matter ; but the Causes of these Principles are kept as Secrets in the Bosom of Nature. The Brain is a Heap of exquisitely fine Glands, and the Nerves are their excretory Ducts ; from whence we are persuaded that they contain the most subtile Matter in the Body, though it is beyond our Power to demonstrate its Existence to any of the Senses : So that the two main Principles upon which I have founded my Theory of *Muscular Motion*, are so intricate and obscure, that we are not able to discover the Cause of the former, nor absolutely to prove the Existence of the latter : But notwithstanding this, what I have advanced, seems, at least to me, so very like the frugal Simplicity of Nature, that the more I think of it, the more I am convinced of its Truth.

THE whole Foundation of natural Philosophy, (as Dr. CHEYNE† observes) is Simplicity and Analogy; or a simple, yet beautiful Harmony, running through all the Works of Nature in an uninterrupted Chain of Causes and Effects, with proper Limitations and Circumstances: And if these Principles be superseded, or this Chain broken, we can expect nothing but Absurdities and Inconsistencies in Philosophy. For Simplicity and Harmony are the surest Marks that the Discoveries made are of the true Kind, and Analogy, the best Rule to make them by.

BUT before I conclude this ESSAY, it may be proper to obviate an Objection which might otherwise be raised against it; viz It may seem reasonable to think that the Contraction of the Fibres of the voluntary Muscles will press upon and hinder the Influx of the animal Spirits after the same manner that I suppose it does in the Fibres of the involuntary Muscles; since there

† Philosophical Principles of Medicine.

is no Difference, that we know of, in their Conformation, and consequently it would then be out of our Power to keep any of the voluntary Muscles in a State of Contraction so long as we are well known to do.

To which I answer; There is no doubt but the voluntary Muscles would be alternately contracted and relaxed as the involuntary ones are; and it would be entirely out of our Power to contract any of the voluntary Muscles a good while together, was it not for the fresh *Impetus* which the Will is capable of giving to the Spirits in those Nerves which go to the voluntary Muscles. Now 'tis from this additional Force or Impulse which is constantly applied to the animal Spirits, when we contract any of the voluntary Muscles, that I suppose they become able to remove the little Resistances they meet with at the Extremities of the Nerves, from the Contraction of the muscular Fibres; and by this Power the animal Spirits do continue to fly into the voluntary Muscles, and there may be a constant Contraction of them as long as the Will

Will is able to direct the Spirits with a sufficient *Impetus* : Whereas this additional Power, which the Will impresses on the Spirits, cannot be supposed to be communicated to the Nerves of the involuntary Muscles ; and consequently, for want of this Assistance, their Extremities, may be slightly block'd up, and the Influx of the Spirits interrupted, 'till the Fibres are dilated again.

BUT this may be more clearly explain'd, by an Observation which I have many times made on those People who are afflicted with a Shaking Palsy : *viz.* That tho' the Muscles of the *Carpus* are alternately contracted and relaxed, and the Hand is thrown about from Place to Place, when the Person does not at all think of it ; yet if he has a mind to grasp any Thing in his Hand, 'tis always in his Power (except in the last Degree of this Illness) to keep the very same Muscles in a steady State of Contraction for some little Time.

HENCE it appears, that when the Nerves are so far weaken'd and relaxed that the Spirits fly through them involuntarily, the voluntary Muscles
become

become involuntary ones, and they are alternately contracted and relaxed, for the same Reason that the Heart itself is : But when the Mind, like a skilful Musician, strikes upon those Nerves which go to these Muscles, it impresses a greater Force than usual to the animal Spirits ; by which means they remove such little Compressions or Constrictions as we suppose to be at the Extremities of the Nerves, and open a Passage into the muscular Fibres as long as the Will is capable of directing the animal Spirits to these Muscles with a sufficient *Impetus*.

F I N I S.



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